Machinery & Energetics
Vol. 15, No. 2. 2024

Journal homepage:
https://technicalscience.com.ua/en

UDC 622.2:624
DOI: 10.31548/machinery/2.2024.09

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Engineering aspects and improvement of well drilling technologies at the Altyguyi field

Abstract. The relevance of the research is justified by the rapid development of the oil industry, which requires constant improvement of methods and equipment to increase extraction efficiency and reduce environmental impact. The aim of this study is to enhance the current engineering aspects of drilling in the Altyguyi field while considering increased productivity and reduced environmental impact. Among the methods used, it is necessary to mention the synthesis method, abstraction method, generalization method, induction method, deduction method, classification method, and others. This study examines the technological aspects of operating wells in the Altyguyi gas-condensate field. Extensive laboratory and industrial research on the properties and composition of oil, gas, and condensate was conducted to properly implement the dual completion technology for gas extraction from one formation and oil extraction from another formation in a single well. By implementing advanced drilling methods, including horizontal and multi-hole drilling, as well as using modern drilling fluids, it was possible to improve well productivity and reduce drilling time. As a result of technology optimization, the overall efficiency of the oil and gas extraction process in the field has been increased, confirming the significance of innovation implementation for improving results in the oil industry. These enhancements not only increased drilling safety and efficiency, but also reduced the negative impact on the environment, emphasizing the importance of integrating modern technologies with environmental considerations in the oil extraction process. This research makes a significant contribution to the development of more efficient and environmentally sustainable drilling methods in oil fields, contributing to increased oil extraction productivity and reduced environmental impact

Keywords: oil industry; efficient production; environmental impact; best practices; drilling fluids

INTRODUCTION

The study of engineering aspects and improvement of well drilling techniques in the Altyguyi field is of strategic importance in the context of ensuring efficient and sustainable energy production. The field represents a significant oil and gas resource, and optimizing drilling processes has a direct impact on its economic value and long-term sustainability. The development of advanced drilling technologies and techniques will increase productivity, reduce operating costs, minimize environmental risks, and maximize production yields, which in turn contributes to the energy security of the region and the country as a whole.

The study includes a set of challenges, such as the complex geological structure of the reservoir, the need to improve production efficiency while adhering to strict safety standards and considering limited resources and costs. The field is characterized by a complex geological structure of the reservoir, which creates challenges in accurately determining its parameters and properties. This requires the development of methods and technologies capable of adapting to the variable conditions of the geological formation and ensuring accuracy when drilling wells. There is a need to improve the efficiency of hydrocarbon production in the

Article's History: Received: 31.01.2024; Revised: 30.04.2024; Accepted: 29.05.2024.

Suggested Citation:
Deryaev, A. (2024). Integration of advanced technologies to improve the efficiency of gas condensate field development. *Machinery & Energetics,* 15(2), 9-20. doi: 10.31548/machinery/2.2024.09.

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field. This includes the development of innovative drilling methods, optimization of oil and gas lifting and handling processes, and improved systems for monitoring and controlling production processes. Environmental and safety standards place high demands on field operations, which requires the development and implementation of technologies aimed at reducing the environmental impact and risks of production processes (Issa *et al.*, 2024). All these aspects require a continuous innovative approach to the development and implementation of drilling technologies capable of ensuring sustainable and safe operation of the field.

In the work of Sh.E. Avulov & A.S. Agyshev (2023), the authors, emphasize that the development of innovative drilling technologies requires combining advanced drilling techniques with high-tech process control and management systems. This will improve the efficiency and safety of production, minimize costs and reduce environmental impact. The paper does not sufficiently cover the aspects of automation of drilling processes and the use of robotic systems to improve the efficiency and safety of operations. According to a study by J.M. Kabyl (2023), successful implementation of new drilling technologies in the field requires cost-effectiveness analyses and estimation of implementation and operation costs. Equipment costs, labour costs, investment payback periods and potential financial risks need to be considered. The study does not consider the factors of economic efficiency of the long life of new technologies and their impact on the competitiveness of the field.

Researchers E. Soatov & H. Ergashev (2023) note that improving the efficiency of field production should be accompanied by strict compliance with safety and environmental standards. It is necessary to develop and implement monitoring and control systems that will ensure the safety of personnel, prevent accidents, and reduce the environmental impact of production processes. Researchers do not pay attention to the development of preventive control and accident prevention systems in the field. In the work of R.O. Nurlybaev (2021), the author raises an important issue that the development of drilling technologies should be included in the overall strategy for the development of the energy sector in the region. It is necessary to take into account both geopolitical and economic factors, assess the potential contribution to the energy security of the country and develop long-term plans for the development of hydrocarbon production. The study does not consider the impact of global trends in the energy sector, such as the transition to renewable energy sources, on the long-term development prospects of the field.

The purpose of this study is to improve the existing engineering aspects of the drilling process at the Altyguyi field with an eye to increasing efficiency and reducing negative environmental impact.

MATERIALS AND METHODS

The study region was the Altyguyi location. Drilling rigs of the model "Drilling Unit-5000" (DU-5000) were considered during the study. These rigs were represented by two variants: diesel Uralmash-ZD (factory diesel), and electric diesel ZJ 70 DS (Zoomlion Heavy Industry Science & Technology Co., Ltd. (Zoomlion), China).

The analytical method applied in the study allowed a comprehensive study of various aspects of the drilling process in the Altyguyi field. By collecting data on well specifications, production conditions, equipment utilization and other factors, the main factors affecting drilling performance and efficiency were identified. In addition, by studying environmental parameters and assessing the environmental impact of production, it was possible to identify the most critical aspects and develop proposals to reduce the negative environmental impact.

Using the synthesis method, comprehensive strategies and recommendations were developed to improve the drilling process at the Altyguyi field. By integrating this research with engineering knowledge and experience, new approaches were developed to optimize drilling parameters, equipment selection and process control methods. In addition, the synthesis method allowed environmental aspects to be effectively integrated into the field development strategy, offering innovative technologies and methods to minimize the negative impact on the natural environment.

The method of synthesis helped in highlighting key trends and general patterns based on a variety of data and research results. By studying the information obtained, the main trends and factors determining the efficiency and sustainability of the drilling process at the Altyguyi field were identified. This method allowed forming a holistic view of the state and prospects of hydrocarbon production development, as well as identifying key areas for further research and development.

Applying the induction method, general regularities and trends were identified on the basis of specific observations and data obtained during the study of the Altyguyi field. This method allowed highlighting the main cause-and-effect relationships between various parameters and factors affecting the efficiency of the drilling process. By examining a variety of data on well specifications, production conditions and environmental impacts, general patterns were identified, which became the basis for formulating recommendations to optimize the drilling process and improve its efficiency.

The deduction method helped in forming logically sound conclusions based on generally accepted principles and theories applied to the specifics of the object under study – the drilling process at the Altyguyi field. By examining generally accepted engineering and environmental principles, as well as already available data on drilling at similar fields, this method was applied to formulate hypotheses and assumptions regarding optimal drilling strategies, ways to reduce environmental impact and improve the overall efficiency of the production process at the Altyguyi field.

The classification method was used to structure the various aspects and parameters that characterize the drilling process in the Altyguyi field. This method allowed the

identification of the main categories and groups of factors affecting the efficiency and environmental sustainability of mining. By examining the data and results, key trends and problem areas requiring further investigation and improvement were identified. Also, the classification method helped to develop more accurate and targeted strategies to optimize the drilling process and reduce its negative environmental impact.

By applying the abstraction method, the main general principles and patterns underlying effective drilling strategies for the Altyguyi field were identified. This method allowed separating the key success factors from the general description of technological solutions. The results of this method allowed creating a generalized model that can be adapted to different conditions and specifics of the field.

RESULTS

At the gas and condensate field in the Altyguyi region, the introduction of closed-loop gas lift compressor technology is becoming a key issue. This innovative system plays an important role in ensuring high quality gas treatment for gas lift operations and continuous gas supply to the export pipeline. The strategic implementation of this system promotes operational efficiency and meets environmental and quality standards, making it an integral component of future field development plans. Drilling depths for production wells in the Altyguyi field vary depending on the structural position. Typically, drilling depths average approximately 3,750 m in consolidated areas and reach approximately 4,000 m in the krill parts. It is important to note that all the project wells are vertical (Deryaev, 2023b).

The design of the wells is carefully selected and justified, taking into account the compatibility of their sections under the current mining and geological conditions of the drilling process. These evaluations are based on analyses of reservoir pressure and rock fracture pressure prediction curves, which are usually presented in combined pressure plots. Taking all these factors into account, the well design is tailored to the specific geological and operating conditions of the Altyguyi field to ensure efficient and safe resource extraction. The methods used are in line with industry standards, safety requirements and the collective experience of previous drilling operations in the region.

The following construction structures are used to ensure safe and efficient drilling of wells at a depth of 3,750 m inside the productive horizon of the Well Construction Structure (NK-9), especially in stable mining and geological conditions:

- the guide section consists of Ø720 mm diameter pipes with a length of 10 m, the purpose of which is to prevent erosion of the wellhead and to provide a secure tie-in to the drilling fluid circulation system;
- the extended length section 30 m long and Ø530 mm is used to support the blowout preventer and provide stability while drilling under the conductor;
- the conductor section, consisting of 426 mm diameter pipe and 400 m long, is used to overcome unstable sandy clay quaternary deposits and provide safe well control;
- the first section of the intermediate string with a diameter of Ø324 mm and a length of 1,600 m is used to reduce the risk of hydraulic fracturing by increasing the density of the drilling fluid;
- the second technical string, which is 3,460 m long and Ø324 mm, is used to control the operation of blowout preventer equipment and to cap high-pressure reservoirs;
- the production string consists of Ø140 mm pipes and extends to a depth of 3,750 m, where resources are extracted from the productive horizon.

The well is cemented all the way to the wellhead (Deryaev, 2023c). To solve the geological problems in the krill part of the NK-9 productive horizon, production wells with a depth of 4,000 m are constructed using the following design: 720 mm diameter pipes, lowered by 10 m, prevent erosion of the wellhead, and provide a connection to the drilling fluid circulation system for its efficient movement, preserving the integrity of the wellhead. Ø530 mm pipes at a depth of 30 m protect the wellhead from erosion and cover areas of high gas saturation at shallow depths due to loose sandy-clay deposits. The 426 mm diameter conductor pipes extend for 600 m, crossing water pressure boundaries and isolating the well from hydraulic connections to surface water, preventing gas contamination and providing control during drilling. The first intermediate string with Ø324 mm pipes reaches a height of 2,000 m, protecting against cave-ins and drilling mud absorption by quaternary sediments. The Ø245 mm pipes in the second intermediate string extend to 3,750 m, providing well control and equipment installation in the NK-7 and NK-8 gas condensate horizons. The production string with Ø140 mm pipes extends up to 4,000 m, creating conditions for testing productive formations and carrying out workover operations, considering the data of gas-dynamic studies.

The detailed design of the well structure in the krill section of the Altyguyi field takes into account the unique geological and operational conditions to ensure safe and efficient drilling and successful resource recovery (Fig. 1). Well construction involves several stages, each requiring specific materials and methods (Adjei *et al.*, 2022). The use of cement to form a protective barrier along all the strings extending to the wellhead. This step is key to ensure the structural strength and reliability of the well. The drilling process is rigorously planned and the choice of drilling mud depends on the particular string being worked on. An oil-emulsion humate-lignosulfonate mud is preferred as a conductor. For the intermediate and production string, a polymer-based drilling mud known as ALKAR-3 is used. It should be noted that when drilling production wells, the coring process is not performed on a regular basis. Instead, selective core samples are chosen to analyse their filtration characteristics in more detail. This approach is used to develop effective strategies for discovering aquifers without the risk of contamination or damage.

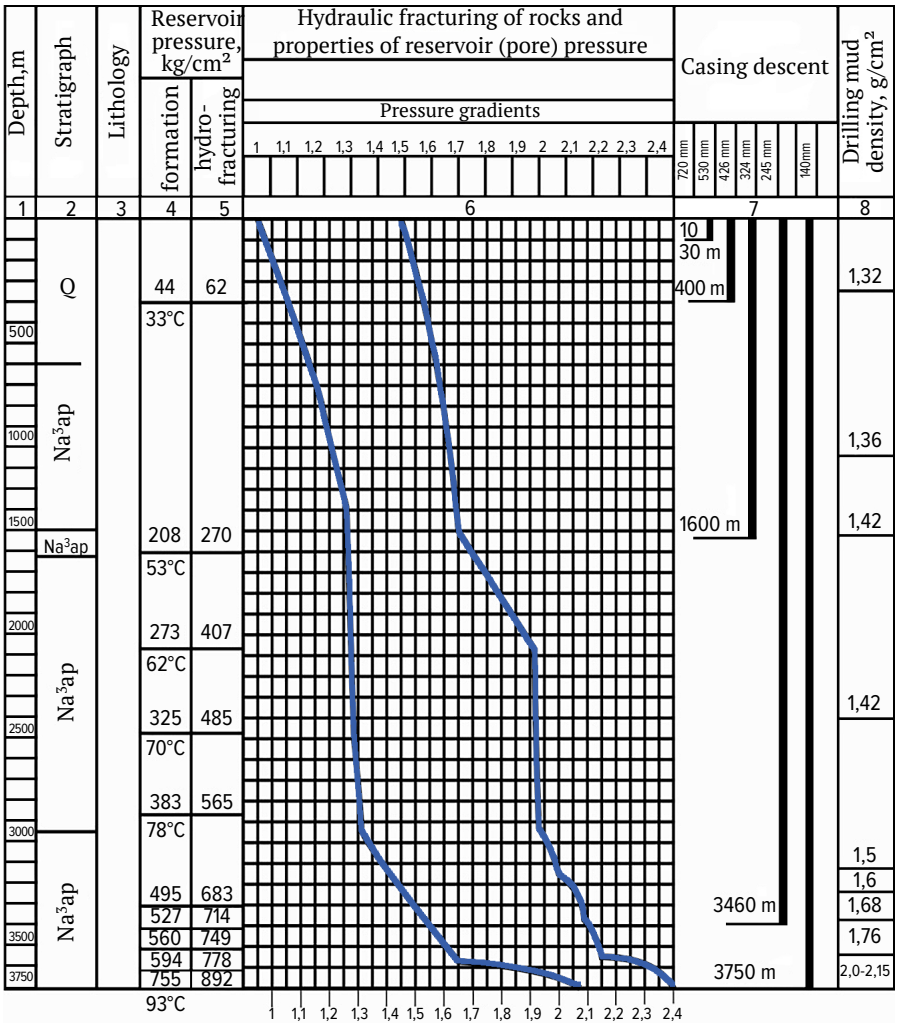

Figure 1. Combined pressure graph at the Altyguyi field
Source: compiled by the author

A well plan is a carefully designed strategy that includes the prudent selection of drilling fluids and equipment to ensure a continuous and efficient process (Pink *et al.*, 2012). To achieve optimum wellbore performance, water-based clay muds are used, enriched with barite to increase density, and treated with chromolignosulfonate-based chemical additives for high performance. To further enhance fluid properties, cement inhibition is used to ensure well stability and reliability throughout the well construction process. This integrated approach emphasizes the importance of strategic planning and integration of advanced technologies for successful well construction projects. This plan requires drilling rigs from the BU-5000 series. These rigs are available in two versions: diesel Uralmash-ZD and diesel-electric ZJ 70 DS. They are specially designed to meet the specific requirements of the drilling process, especially in difficult desert terrain.

The Uralmash-ZD drilling rig (Fig. 2) in the diesel version is technologically advanced equipment with a number of important features that make it indispensable in the oil industry. One of the key features of this unit is that it is equipped with a diesel engine. This type of engine provides high torque and reliable operation even in conditions with intermittent or limited power supply. In addition, the Uralmash-ZD drilling rig has high power and characteristics that allow it to effectively drill in a wide variety of conditions, including difficult desert terrains. Its ability to operate in such extreme conditions makes it indispensable for many projects where reliable and efficient well drilling is required. The performance and reliability of the Uralmash-ZD drilling rig is another of its important advantages. Thanks to its design and technical characteristics, this rig is able to provide high drilling speed and minimum downtime, which increases the efficiency of projects and reduces time and financial costs. Last but not least, the Uralmash-ZD drilling rig is specially adapted to work in environments where access to the power grid is limited. This makes it an ideal choice for projects in remote or underdeveloped regions where the electrical infrastructure leaves much to be desired. Thus, the Uralmash-ZD diesel drilling rig is a reliable and powerful tool capable of efficiently performing various drilling tasks in the most challenging conditions.

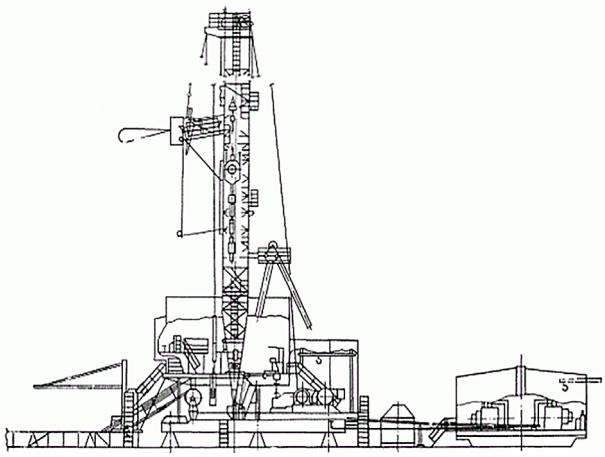

Figure 2. Diagram
of the Uralmash-ZD drilling rig (diesel version)
Source: H. Suryadi *et al*. (2021)

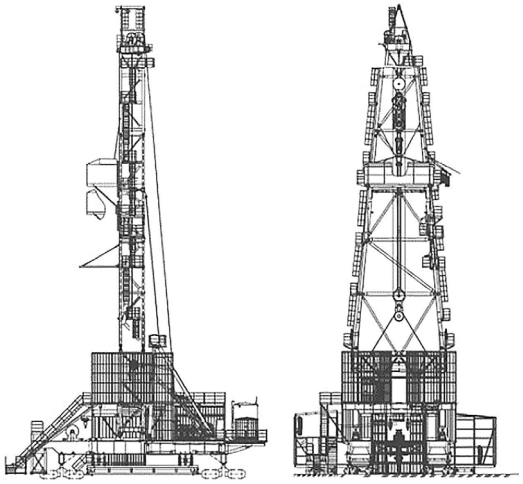

Figure 3. Diagram
of the ZJ 70 DS drilling rig (diesel-electric version)
Source: A. Deryaev (2023a)

The ZJ 70 DS diesel-electric drilling rig is innovative equipment that provides optimal solutions for a variety of drilling projects in conditions of varying complexity. Its main difference is the diesel-electric system, which gives the rig significant advantages in efficiency and energy efficiency. With this type of system, the rig provides stable and reliable operation while minimizing fuel consumption, which is an important factor in reducing operating costs and environmental impact. In addition, the ZJ 70 DS offers a versatile solution for drilling in a wide range of conditions. Its high mobility allows the equipment to be easily moved and quickly set up to work in different geological conditions and climatic zones. This makes it an ideal choice for projects requiring rapid deployment and flexibility to adapt to changing conditions.

One of the key advantages of the ZJ 70 DS drilling rig is its ability to deliver high efficiency in operation. Thanks to its electric power supply and efficient system control, the rig is able to provide stability and accuracy during the drilling process, resulting in increased productivity and reduced project time. In addition, the ZJ 70 DS drilling rig is adapted to work in remote areas where access to the main power grid may be limited. This makes it ideal for projects in remote or poorly developed areas where reliable and efficient drilling equipment is required. In summary, the ZJ 70 DS diesel-electric drilling rig is an advanced piece of equipment that combines high efficiency, mobility, and energy efficiency, making it an indispensable tool in today's oil industry (Fig. 3). To ensure a smooth drilling process in the harsh desert environment, additional equipment is required, such as blowout preventer systems and specialized devices for preparing, cleaning, and storing weighted drilling fluids. These additions are critical (Kuyken *et al.*, 2021). Drilling operations must strictly adhere to the drill string bottom patterns established by the Drilling Technology Laboratory at Nebitgazylmytaslama (Ashgabat, Turkmenistan). These recommended schemes are designed to prevent borehole curvature.

Their use avoids additional well design and drilling prior to casing installation, thereby speeding up the entire drilling operation and reducing potential problems. This method ensures that the borehole is kept securely on track, which increases the efficiency of the process and minimizes potential drilling problems.

To ensure an efficient drilling process, it is recommended to use a high-performance tricone steel bit with a carbide tip, graphite coating and elongated shape, used for universal operations (S-TSGVU) (Fig. 4), manufactured by V. Bakul Institute for Superhard Materials (Ukraine), is another variant of the tricone bit. It is designed for drilling in hard and tough rocks such as granites, gabbro, and basalts and is equipped with synthetic diamond-reinforced cones that provide maximum wear resistance and ability to drill in extreme geological conditions, as well as high mechanical speed.

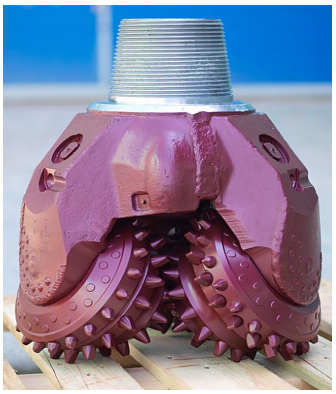

Figure 4. Bit S-TSGVU
Source: C.W. Kuyken *et al.* (2021)

To achieve precision and efficiency in drilling, it is necessary to strictly control operational parameters in accordance with the technical project or geological-technical

assignment. As drilling progresses, a meticulously developed plan for conducting comprehensive geophysical well studies is activated, incorporating various tools and methods. Each of them serves its unique function in enhancing our understanding of subsurface conditions. This comprehensive package includes standard logging, cavernometry, profiling, lateral logging, gamma logging, neutron logging, acoustic logging, thermometry, and inclinometry, representing just a few logging methods. All these operations are conducted with the highest precision and detail on a 1:500 scale for each well. Such thorough analysis provides us with extensive knowledge of subsurface conditions and enables us to make informed decisions at all stages of drilling and subsequent operations.

To achieve the highest technological efficiency, filtration and rheological characteristics of the drilling fluid are meticulously adjusted (Li *et al.*, 2023). This crucial stage ensures that the drilling fluid composition is optimized for the specific operation requirements. The procedure of treating the drilling fluid before penetrating the productive geological formation aims to reduce water production and impart filtrate properties that prevent contamination of surrounding formations. This strategic approach not only contributes to the successful completion of the drilling process but also minimizes negative environmental impacts, ensuring the preservation of underground reservoirs. To fully understand changes in oil and gas reserves in formations and maximize their recovery, a series of complex studies is required. These studies include hydrodynamic analyses, field-geophysical assessments, and laboratory research. The main goal of such studies is to deeply investigate the nature of variations in reservoir hydrocarbon potential and ensure optimal and comprehensive resource extraction during oil and gas field exploitation. By combining these methods, a comprehensive understanding of reservoir dynamics is achieved, enabling informed strategic decisions regarding resource extraction and reservoir management.

Effective management of oil and gas fields, as well as monitoring the condition and performance of wells and equipment, requires the use of a complex set of research and monitoring methods. This set of methods should include the assessment of various parameters of current producing wells, such as formation, bottomhole, and surface pressures. Measurement of these pressures should be conducted regularly and systematically. Bottomhole pressure should be monitored when new wells are brought into production and after major repairs, as well as systematically measured in existing wells at least twice a year. Determining formation pressure is also crucial and should be performed for all wells with productive formations, including those within legal boundaries. These measurements should be taken after drilling or repair operations are completed and regularly, no less than once every six months for active producing wells. Sampling investigations before and after repairs or other geotechnical interventions that may affect the near-wellbore zone should also be conducted. Additionally, comprehensive studies of active producing wells should be conducted at least once every two years. Pressure build-up studies are also beneficial and should be conducted for all new and repaired wells, with planned pressure build-up tests conducted no less than once every two years for active producing wells. These methods are necessary to ensure safe, efficient, and productive operation of oil and gas wells. Regular monitoring and assessment of pressure parameters play a crucial role in maintaining reservoir integrity, optimizing production, and preventing potential issues. By implementing these comprehensive research and monitoring protocols, the industry can make informed decisions, maximize resource recovery, and enhance the long-term sustainability of oil and gas production.

Furthermore, active monitoring and control of changes in current and overall production of oil, water, and gas throughout the field are crucial. This monitoring should cover all formations, zones, and each individual well to ensure effective and stable exploitation of oil and gas reserves. For wells operating in multiple formations, it is recommended to use various research methods, often combining them with geophysical techniques. These methods include inflow analysis, monitoring of contact and saturation zones, temperature determination, evaluation of production tubing, assessment of gas lift valves, sample collection and oil analysis, as well as obtaining samples for physicochemical tests. All these measures ensure optimal conditions for oil and gas fields, enabling efficient and environmentally friendly extraction of these valuable resources. In-depth analysis of geological and operational data has identified shortcomings in the hydrodynamic characteristics of several wells actively used in production. These shortcomings relate to their interaction with productive formations. To optimize the performance of these wells, it is necessary to accurately determine completion and perforation locations, especially in areas with high gas content, which is particularly important for gas condensate production projects in this region.

To increase the efficiency of low-productivity wells, two key methods are recommended (Li *et al.*, 2023). The first method involves treating the near-wellbore zone of the formation with clay acid to dissolve clay particles and other obstacles hindering hydrocarbon flow. This may contribute to improved reservoir connectivity and overall productivity. The second method, hydraulic fracturing, is also an important approach. This method involves creating fractures in the reservoir by injecting fluid under high pressure into the wellbore. These fractures allow hydrocarbons to be extracted from previously inaccessible zones, significantly increasing well productivity. Implementing simultaneous well operations has yielded promising results, especially at the Altyguyi field, where this approach is recommended to be extended to low-productivity wells both in the tubing and annulus spaces. The use of a comprehensive approach, including pinpoint completions and perforations, clay acid treatment, hydraulic fracturing, and continued simultaneous well operations, allows for a significant increase in their productivity and overall efficiency at the Altyguyi field.

During well operation, systematic monitoring and analysis are carried out to ensure the reliability of the production column, equipment integrity, and compliance with established technological parameters (Burton *et al.*, 2021). The main goal of this process is to collect data for optimizing technological processes and increasing production efficiency. Within the monitoring framework, a comprehensive inspection of wells and associated equipment is conducted. This includes checking the integrity of cement, the condition of casing and pump-compressor pipes, analysis of the near-wellbore zone of the formation, as well as checking for well contamination and equipment operability at various depth levels. The main task of monitoring is to ensure compliance with equipment performance parameters and the technical mode of the well. This guarantees optimal equipment operation and maximum production efficiency. Continuous assessment of the reliability and operability of equipment components is also an essential part of the monitoring process. This allows for timely identification of malfunctions and conducting repair work, minimizing downtime, and ensuring reliable operation. The collected data is used for planning repair work and optimizing technological processes in wells. This contributes to increased productivity and ensures stable well operation in the long term.

Regular monitoring and analysis of well performance play a key role in ensuring the safety, efficiency, and overall productivity of the production process. This ensures reliable operation of equipment and wells under established standards, which in turn helps make informed decisions regarding technical maintenance and process optimization. Departments responsible for oil and gas production collaborate with research organizations and geophysical companies to determine the types, volumes, and frequencies of necessary surveys and measurements to monitor equipment performance under various well operation methods (Fan *et al.*, 2021). Decisions are made in conformity with project proposals and ultimately approved by association management. Scientific research aimed at controlling the operation of producing wells must strictly adhere to safety standards in the oil and gas industry and comply with existing regulations for the protection of mineral resources and the environment, ensuring responsible and sustainable well operation (Klemz *et al.*, 2021).

The engineering service within oil and gas production companies is responsible for the systematic study and use of materials for equipment monitoring to ensure compliance with designated well operation modes. All primary research materials, except for echograms and dynamograms (stored for a minimum of three years), must be stored throughout the entire well operation period, ensuring the preservation of a complete data archive for long-term assessment and analysis. Applying these measures will enable the Altyguyi field to maintain gas production at planned levels, ensuring operational efficiency and facilitating data-driven decision-making, ultimately contributing to further success and productivity of the operation. To activate and maximize the potential of idle and underutilized oil wells, it is strongly recommended to carry out a series of activities for their restoration, development, and commissioning. These measures include tasks such as restoring communication between the wellbore and upper and lower reservoirs, performing water isolation procedures based on comprehensive analysis of geophysical research, thorough inspection of production columns, and removal of emergency packers. Throughout these operations, it is crucial to consider the results of geophysical surveys conducted during repairs. Additionally, the use of innovative technologies such as Slickline and flexible tubing plays a crucial role in optimizing the efficiency and effectiveness of restoration work.

The duration of repair work depends on various factors, including geological aspects such as the size of the exploitation zone and proximity to other wells, as well as on-site testing results. Furthermore, the condition of the well and the availability of necessary equipment play a key role in determining the time required for the work. Therefore, it is impossible to accurately predict the schedule of repair work for specific wells in advance. The decision on the feasibility and timing of these projects will be made during field operation, taking into account the individual characteristics of each well. Recent research in the Altyguyi area has included extensive geochemical and hydrodynamic studies aimed at determining the composition of oil, gas, and condensate. These efforts have yielded valuable results, allowing for accurate determination of condensate and natural gas reserves, as well as related calculated characteristics.

Well exploitation in the Altyguyi field is complicated by several factors, including deep reservoirs, variable daily liquid flow rates, high initial pressure, pressure drop, working with under-saturation pressure, high gas coefficient, complex well geometry, reservoir composition changes, and paraffin issues. It is important to consider the unique characteristics of each well and adapt exploitation strategies to their features, as well as prepare for future changes, including adjusting gas lift depths. It is important to note that the adoption of technical and technological decisions can significantly vary depending on the unique conditions of each gas condensate field. The complex interaction of these factors can cause difficulties in fully complying with all requirements, especially in the case of previously drilled wells under certain circumstances. Well depth and casing diameter are major factors that exert significant influence. In the context of existing operational wells, as observed in the Altyguyi field, the use of well equipment fully compliant with gas reservoir development requirements may be limited by the combination of significant well depths and relatively small production column diameters.

Implementing mechanized oil extraction at the Altyguyi field requires a thorough and comprehensive approach, taking into account the interaction of various factors, including geological, operational, and technical aspects. Achieving harmony among these components is critical for production optimization, ensuring high operational efficiency and equipment durability, especially in

conditions unique to this area. The primary goal of comprehensive equipment analysis for gas condensate extraction at the Altyguyi field was to determine the most effective approach to developing the resources of this field. This was achieved by studying various methods of gas condensate separation across three horizons where both oil and gas are present, using the same well. The analysis also involved evaluating sets of well equipment, including technical solutions from renowned global manufacturers. This assessment was based on data obtained from the construction and operation of gas and oil wells at the Altyguyi field.

Assessing the technological characteristics of these equipment systems involves a comprehensive analysis of various key parameters critical for determining their performance and compatibility. Factors considered in such assessment include:

- working pressure, determining equipment operation efficiency;
- maximum gas production capacity, a key indicator for production optimization;
- nominal diameter of lifting pipes, influencing liquid transport within the system;
- minimum borehole diameter, affecting liquid flow and overall efficiency;
- passage diameter for interchangeable choke valves, regulating liquid flow;
- nominal diameter of production tubing, determining overall system productivity;
- external packer diameter, important for wellbore sealing and isolation;
- maximum packer setting depth, influencing its applicability in various well configurations;
- technical conditions of the working environment, ensuring compatibility with the surroundings;
- maximum temperature stability of the working environment, determining equipment's operational limits;
- packer dimensions and weight, influencing installation and transportation logistics, excluding lifting pipes.

Together, these parameters form the basis for comprehensive evaluation, determining the selection and implementation of equipment systems in various operating scenarios. Collectively, they form the basis for assessing the technological capabilities and suitability of the considered equipment complexes.

A comprehensive assessment of these technological characteristics has identified the most suitable equipment set for the effective development of the Altyguyi gas condensate field. This analysis has contributed to defining the optimal approach to extraction and resource management of this unique geological reserve. For the development of the Altyguyi gas condensate field, various complex equipment configurations have been carefully studied, with special attention to the constant current method, which involves extracting gas and oil from three different horizons. In this context, two main configurations have been considered: simultaneous suspension of pump and compressor tubing for dual completion systems. This configuration is designed to facilitate simultaneous gas production by the fountain method and oil production by the gas lift method from three separate horizons. It includes a complex setup that optimizes resource recovery efficiency. Additionally, this configuration has been studied for its potential to provide dual completion, allowing simultaneous gas and oil production. The use of dual hydraulic packers is an important element of this setup, improving control over well operation.

When implementing such a constant current scheme, a key technological aspect is the ratio of predicted depressions within the exploited reservoirs, which is critical for ensuring efficient and effective resource extraction. Analysis of available data shows significant differences in depressions between upper and lower reservoirs during simultaneous gas production from the NK-8 and NK-7 reservoirs through a single oil-gas-condensate production tubing (NKT). It is particularly important to note that the upper layer is characterized by relatively low depression, which is a determining factor for achieving the desired gas production rate. This specific aspect should be considered in the design and operation of equipment complexes. Various factors can potentially contribute to an increase in pressure within the wellbore filtration zone. One such factor involves the formation of seals inside the pump-compressor tubing in the near-surface area or directly in the wellbore, leading to increased wellhead pressure. This may create conditions conducive to inter-reservoir flows, where different fluids from different horizons may mix. However, it should be noted that the risk of such inter-reservoir flows is somewhat reduced during simultaneous exploitation of the NK-7 and NK-8 horizons at later stages of field development. However, it is important to understand that this does not diminish the fundamental requirements for the equipment used.

Oil and gas fields in Turkmenistan represent a unique geological complexity, with multiple layers containing hydrocarbons overlapping each other. This multi-layered geological landscape promises significant potential for resource extraction. However, a balance must be found between strategic development and significant capital expenditures, especially on drilling new wells (Byashimov *et al.*, 2023). One of the most reasonable approaches to developing such multi-layered reservoirs involves creating separate well networks for each layer. This strategy allows for the efficient utilization of resources, considering the unique characteristics and behaviour of each reservoir. However, this approach is associated with significant costs for drilling new wells. In fact, more than half of the total capital expenditures on oil and gas field development go towards drilling. This high financial threshold often questions the economic and technical feasibility of such an approach.

In response to budget constraints, an alternative strategy has emerged. When working with multi-layered reservoirs, it has become common practice to combine multiple productive layers into a single operational unit. This approach optimizes the development process in several ways. Firstly, it reduces the time required for field development, as management of multiple layers is done concurrently.

Secondly, it reduces significant capital expenditures associated with well drilling, improving the overall economic and technical feasibility of the project. Simultaneous development of multiple geological formations by a single operating entity presents an attractive approach, but it depends on several critical factors. It is essential that the physical and chemical properties of oil, gas, and condensate in all integrated layers are consistent. This means that the influx of oil and gas from each reservoir must be sufficient to maintain the corresponding bottomhole pressure in the well. Additionally, the reservoir pressure in the combined layers must be accurately balanced to prevent undesirable oil and gas flows between the layers. It is equally important for the water content in these layers to be consistent.

However, it should be noted that in some cases, it is not possible to ensure compliance with these conditions. When the physical and chemical properties of the reservoirs, their flow rates, pressures, and water content significantly differ, the development of multi-layered deposits requires an alternative approach. In such scenarios, the dual completion method using a single well is employed. The choice of a specific dual completion scheme depends on the unique geological and technical conditions of the field development, as well as the operational characteristics of the involved wells.

DISCUSSION

The implementation of innovative engineering solutions and the improvement of drilling technologies at the Altyguyi field open up new horizons for the efficient extraction of oil and gas from complex geological formations. This process requires a deep understanding of the geological and engineering characteristics of the field, as well as the development of innovative methods and equipment to address emerging challenges. One of the main aspects that requires attention is the depth of the field. In the Altyguyi field, productive reservoirs are located at significant depths, presenting serious technical challenges for drilling and well operation. Specialized drilling rigs and tools capable of ensuring safety and operational efficiency are required to penetrate such depths effectively.

An important direction in drilling technology development is the improvement of control and monitoring processes. Modern drilling methods at the Altyguyi field include the use of advanced monitoring and control systems, such as data logging systems and geophysical technologies, to obtain accurate information about well conditions and the geological environment. This helps minimize risks and enhances drilling efficiency. Another important aspect is the development of engineering designs specifically adapted to field conditions. For example, guide sections and reinforced casing columns can be used to protect wells from erosion and ensure their stability in complex geological conditions. In addition to this, innovative approaches to managing drilling waste and drilling fluid treatment can reduce the negative impact on the environment and increase the sustainability of extraction processes (Ozdoyev *et al.*, 2019). Overall, engineering aspects and the improvement of drilling technologies at the Altyguyi field play a key role in ensuring efficient and safe oil and gas extraction. The development of new methods and technologies adapted to the unique conditions of this field allows for the optimization of production processes and increased overall extraction productivity.

According to the findings of recent research by H. Wang *et al.* (2022), drilling technologies for deep and ultra-deep oil and gas wells are constantly progressing, reflecting rapid changes in the oil and gas industry. With the development of deepwater drilling and drilling on the continental shelf, as well as the discovery of new deposits at significant depths, the need for advanced technologies becomes increasingly relevant. In this context, it is important to discuss both existing progress and prospects in this area. One of the major achievements in the field of deep and ultra-deep drilling technologies is the development of highly efficient drilling systems and tools. Modern drilling rigs have enhanced power and precision, allowing them to overcome technical challenges when operating at great depths (Ihnatov *et al.*, 2022). The application of advanced drilling technologies, such as horizontal and directional drilling, enables increased production volume and reduced drilling and well operation costs. These findings align with the theses outlined in the previous section. In the future, the development of drilling technologies for deep and ultra-deep wells will continue towards increasing automation and the use of artificial intelligence. Automated drilling and monitoring systems will help improve operational safety and efficiency, while machine learning algorithms and data analysis will optimize processes and predict potential issues before they occur.

Referring to the definition by G. Jiang *et al*. (2022), the innovative water-based drilling and completion fluid technology represents a significant step in the development of drilling and well operation methods. This technology is based on the use of special water-based compositions designed to improve wellbore quality and protect unconventional reservoirs. It provides an efficient solution for drilling in various geological conditions, including heterogeneous and sparse reservoirs, and ensures reliable well protection from various issues, such as potential reservoir damage and degradation of their productivity. It should be noted that the advantages of this technology include increased resistance to high temperatures and pressures, as well as improved adhesion properties, which contribute to more effective operation in conditions of increased complexity. Thanks to the use of a water-based solution, this technology is environmentally friendly and does not have a negative impact on the environment (Fedorov *et al*., 2023). Additionally, it reduces drilling and well operation costs by increasing their productivity and reducing drilling time.

A. Bani Mustafa *et al.* (2021) identified that improving drilling performance is a key challenge in the oil and gas industry, and optimizing controllable parameters plays an important role in this. This approach aims to enhance the

efficiency and accuracy of the drilling process, ultimately reducing project duration and costs. Optimization of controllable parameters includes various aspects such as drill rotation speed, drilling fluid pressure, drill bit selection, and the use of modern control and monitoring systems. These findings confirm the aforementioned study, as the implementation of modern technologies and automation systems allows for more precise control of these parameters, adapting them to the specific conditions of each well. This provides optimal drilling conditions in both standard and complex geological conditions, contributing to increased drilling speed and efficiency. Ultimately, optimizing controllable parameters not only reduces project duration but also improves its effectiveness, enhancing overall productivity and economic benefits (Stavychnyi *et al.*, 2023).

F. Farahbod (2021) demonstrated through their work that experimental research on the thermophysical properties of drilling fluid using nanoparticles represents a promising approach to enhancing drilling efficiency. The integration of nanotechnologies into drilling fluid compositions significantly improves their characteristics, leading to a more efficient well drilling process. Nanoparticles added to the fluid can influence its thermophysical properties such as thermal conductivity and heat capacity, opening up new possibilities for optimizing heat transfer during drilling (Dzhalalov *et al.*, 2021). This opinion agrees with the main advantages of using nanoparticles in drilling fluids, which include increased heat transfer in the drilling zone, improved control over temperature regimes, and reduced risk of negative consequences associated with equipment overheating and wellbore deformation. This is particularly relevant for drilling deep and complex wells where thermal regimes play a crucial role. Therefore, experimental research on the thermophysical properties of drilling fluid with nanoparticles represents an important direction for development aimed at enhancing drilling efficiency and reducing costs.

As noted by S.W. Lai *et al.* (2021), the widespread implementation of a closed-loop drilling optimization system is a key stage in the development of modern technologies in the oil and gas production field. This system incorporates comprehensive data monitoring and analysis methods, allowing real-time adjustment of drilling parameters according to changing well conditions. The main goal is to increase drilling productivity, reduce costs and risks, and improve operational safety. Implementing a closed-loop drilling optimization system at fields demonstrates significant results. It enables prompt responses to change in geological conditions, maintains drilling process stability, and optimizes the use of drilling equipment. Analysing the obtained results and conclusions, it is evident that through automation and algorithmic drilling process management, efficiency, and accuracy improvements are achieved, as well as task completion time reduction. Such innovative solutions play an important role in enhancing the competitiveness of companies in the oil and gas industry market (Ivanenko, 2023).

M.R. Isbell *et al.* (2021) determined that the integration of digital technologies into well planning and construction opens up new prospects for efficient operations at fields. Using modern software solutions and algorithms allows for more detailed and precise modelling of drilling processes. This includes analysis of geological data, drilling trajectory optimization, and forecasts of well productivity. Additionally, digital technologies also provide the opportunity for multi-faceted planning, allowing engineers and drilling specialists to consider numerous factors when making decisions. This includes accounting for geological features of the field, equipment technical characteristics, safety conditions, and environmental factors. As a result, it becomes possible to develop more reliable and optimized action plans, contributing to increased efficiency and reduced costs in well drilling projects.

CONCLUSIONS

In the Altyguyi field, engineering aspects play a key role in optimizing and improving well drilling techniques. Due to the geological peculiarities of this area, which include significant well depths and variability in reservoir characteristics, it is necessary to continuously develop methods and equipment for efficient oil and gas production.

One of the key areas of technology improvement is the introduction of modern modelling and forecasting techniques that allow for more accurate determination of well parameters and selection of optimal drilling strategies. This includes the use of specialized computer programmes to analyse geological data, predict pressures and calculate well performance, which significantly increases the efficiency and accuracy of the process of designing and developing oil and gas fields. Also, an important area is the research and development of innovative drilling fluid technologies, which are aimed at improving wellbore quality and protecting reservoirs from possible damage. The introduction of such technologies makes it possible to reduce the time and costs of the drilling process and significantly improve the efficiency of hydrocarbon resource extraction at the fields. Importantly, there is a drive to increase drilling productivity by optimizing controlled parameters and implementing innovative control systems. This includes the use of automated systems for monitoring and controlling the drilling process, which facilitates more accurate control and prevention of potential problems, ensuring more efficient and safer field operations.

In summary, improvements in drilling technology in the Altyguyi field are aimed at increasing efficiency, ensuring safety, and achieving economic benefits in the oil and gas production process, which is a key aspect for the sustainable development of the oil and gas industry in the region. Further research should focus on developing and testing new drilling technologies that can improve production efficiency and reduce environmental impacts in the Altyguyi field.

ACKNOWLEDGEMENTS

None.

CONFLICT OF INTEREST

None.

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Інженерні аспекти та вдосконалення технологій буріння свердловин на Алтигуйському родовищі

Анотація. Актуальність дослідження обґрунтована стрімким розвитком нафтової промисловості, що вимагає постійного вдосконалення методів і обладнання для підвищення ефективності видобутку та зниження екологічного впливу. Метою даного дослідження є поліпшення поточних інженерних аспектів буріння на Алтигуйському родовищі з урахуванням підвищення продуктивності та зниження екологічного впливу. Серед використаних методів слід зазначити метод синтезу, метод абстрагування, метод узагальнення, метод індукції, метод дедукції, метод класифікації та інші. У цьому дослідженні розглянуто технологічні аспекти експлуатації свердловин Алтигуйського газоконденсатного родовища. Для правильної реалізації технології подвійного закінчування для видобутку газу з одного пласта і видобутку нафти з іншого пласта в одній свердловині були проведені великі лабораторні та промислові дослідження властивостей і складу нафти, газу і конденсату. Шляхом впровадження передових методів буріння, включно з використанням горизонтального і багатостовбурного буріння, а також застосуванням сучасних бурових розчинів, вдалося досягти поліпшення продуктивності свердловин і скорочення часу на буріння. У результаті оптимізації технологій вдалося підвищити загальну ефективність процесу видобутку нафти і газу на родовищі, що підтверджує значущість впровадження інновацій для поліпшення результатів у нафтовій промисловості. Ці удосконалення не тільки підвищили безпеку та ефективність буріння, але також знизили негативний вплив на навколишнє середовище, що підкреслює важливість інтеграції сучасних технологій з урахуванням екологічних аспектів у процесі нафтовидобутку. Це дослідження робить значний внесок у розробку більш ефективних і екологічно стійких методів буріння на нафтових родовищах, сприяючи підвищенню продуктивності нафтовидобутку і зниженню негативного впливу на навколишнє середовище

Ключові слова: нафтова промисловість; ефективний видобуток; екологічний вплив; передові методи; бурові розчини